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ABSTRACT

To probe a psychological theory of educational productivity, background measures along with mathematics test scores and motivational measures of over 7,000 students (9-, 13- and 17-year olds from National Assessment of Educational Progress samples) were statistically related to each other and to indicators of constructs that prior research shows are associated with learning outcomes. Covariance structure analysis methods were used to evaluate the causal relation among student background characteristics, motivation and achievement measures. Results of this study indicate the importance of the student motivation factor in understanding student learning outcomes. The role of motivation as an educational productive factor became more important for students as they increased in age from early adolescence to late adolescence. The influence of home background on achievement was significant at all ages while also showing a more general positive relationship over the adolescent years. (Author)

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An Evaluation of Causal Modeling Applied to Educational Productivity in Mathematics

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Paper prepared for presentation at the 1982 annual meeting of the American Psychological Association, Washington, D.C., August 1982.

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Abstract

To probe a psychological theory of educational productivity, background measures along with mathematics test scores and motivational measures of over 7,000 students (9-, 13- and 17-year olds from National Assessment of Educational Progress samples) were statistically related to each other and to indicators of constructs that prior research shows are associated with learning outcomes. Covariance structure analysis methods were used to evaluate the causal relation among student background characteristics, motivation and achievement measures. Results of this study indicate the importance of the student motivation factor in understanding student learning outcomes.

The role of motivation as an educational productive factor became more important for students as they increased in age from early adolescents to late adolescents. The influence of home background on achievement was significant at all ages while also showing a more general positive relationship over the adolescent years.

An Evaluation of Causal Modeling Applied to Educational Productivity in Mathematics

Introduction

Traditionally, research on the effects of formal schooling has focused on the influence of classroom social environments. Comprehensive reviews on the influence of classroom social environments have recently been conducted (Moos, 1978; Walberg, 1981). Numerous approaches are reviewed which describe the assessment of the classroom environment. For example, Van Horn (1976) described as objective indicators of the classroom environment different teacher verbalizations and classroom activities. Wiley and Harnischfeger (1982) more recently have used self report forms completed by classroom teachers to describe the complexity of the classroom environment. Others have attempted to measure self-reports or perceptual indicators of the classroom learning environment (e.g., Anderson & Walberg, 1974; Barclay, 1974; Di Marco, 1974; Trickett & Moos, 1973).

Variables describing the classroom learning environment for the most part have been regarded essentially in terms of their instrumental value as an influence on various educational outcomes. On the other hand, some research has focused on such behavioral goals that include student morale, educational aspiration, creativity or personal growth while for the most part research on the effects of classroom learning environments has focused on the educational outcomes in terms of standardized test performance, competency tests of basic skills, grades or other measures of academic achievement (e.g., Brookover, 1981; Brookover, Schweitzer, Schneider, Beady, Blood, & Wisenbaker, 1978; Harnisch, 1981; Pascarella, Walberg, Junker, & Haertel, 1981). Research results by Moos (1979) suggest that achievement gains are

most likely to occur in classrooms which optimally combine warm and supportive relationships, an emphasis on academic tasks and accomplishments, and a clear, orderly and well structured learning environment.

Results from the Equality of Educational Opportunity (EEO) Study (Coleman, Campbell, Hobson, McPartland, Mood, Weinfield, & York, 1966) indicated that locus of control was the best predictor of achievement among a list of student, social, teacher and school factors. This finding brings to attention the critical importance of motivation and related concepts of self. Previous research reviews reached a similar conclusion regarding the importance of motivation as a critical variable in understanding student learning (Hill, 1980; Uguroglu & Walberg, 1979; Walberg & Uguroglu, 1980).

The primary purpose of this paper is to examine the causal relationships among student background, motivation, and academic achievement conceived as latent variables. Multiple indicators of student background, motivation and academic achievement were used to determine the relationship among the latent variables. Walberg (1981) outlined a list of characteristics that could be considered as production factors of academic achievement. The seven factors identified by Walberg (1981) as showing positive relations with learning are

1) student age,
2) ability level of student,
3) student motivation,
4) quality of instruction,
5) quantity of instruction,
6) social-psychological environment of the class, and the
7) social-psychological environment of the home.

Of specific interest in this paper is the relationship among three latent variables for national samples of early (9-year olds), middle (13-year olds) and late adolescents (17-year olds).

Data Source and Method

The data for the present analyses were obtained from the Education Commission of the States which conducts the National Assessment of Educational Progress (NAEP). Data tapes from the assessment of 9-, 13-, and 17-year olds in Mathematics (1978-79) were used for analysis in this paper.

Sample

A deeply stratified, multi-stage sampling design with oversampling of low-income and rural areas was used by NAEP (National Center for Educational Statistics, 1978; Moore, Chromy, & Rogers, 1974). In the first stage, the United States is divided into geographical units, including Standard Metropolitan Statistical Areas and counties or groups of contiguous counties. These are stratified according to region and size of community. In the second stage, schools are randomly sampled within selected first-stage geographical units. Finally, from 10 to 35 age-eligible students are randomly selected within schools for testing.

Test Packages

The NAEP test materials are organized into booklets suitable for administration in a single sitting. Each booklet or "test package" contains a collection of items taken by a selected student. In the student assessment of mathematics (1978-79), 7 separate test packages were administered to large national representative samples of 9-year-old (early adolescents), 11 separate test packages to 13-year-old (middle adolescents) and 11 separate test packages to 17-year-old (late adolescents) students. Packages 2, 5, and 6 were chosen respectively for the

the national samples of 9-, 13-, and 17-year-old students since it was judged that these test packages had the most adequate representation of the variables being investigated in this research paper.

Sample Characteristics

The characteristics of the samples for the three age groups are summarized in Table 1 with reference to their sample size, proportion of students according to their sex, race/ethnic membership, and parents' education level.

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Insert Table 1 about here

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Variables

The variables used in the analyses could be grouped into three general categories:

1. Student background characteristics
   * sex
   * race/ethnicity
   * mother's formal education
   * father's formal education
   * a measure of home environment
2. Motivational measures
   * degree of liking mathematics scale
   * ease of performing math activities scale
   * importance of mathematics

3. Math achievement measures (scales formed based on NAEP item classifications)

* knowledge and skills
* understanding
* applications

The operational definitions of all variables with sample items are shown in Table 2.

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Insert Table 2 about here

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Variables which are conceived as composites of items similar to those listed in Table 2 (i.e., the home environment scale, the three motivation scales, and the three measures of achievement in mathematics) were scored as percent "correct." For the math achievement measures, the number correct was simply divided by the total number of items. For the motivation measures (items scored on a 1 to 5 scale representing a continuum from low to high) item responses were summed and then divided by the highest possible score (i.e., 5 times the number of items) to yield a percent of maximum motivation score. For the home environment variable, items were scored 1 for yes, 0 for no and then summed and divided by 4, the number of items on the scale. All of these proportions were then transformed by a simple arcsine transformation in order to correct for scaling differences which could result from using proportions based on composites with different numbers of items.

Rationale Behind LISREL Approach

Many approaches to developing and testing models of motivation and achievement have employed multiple regression and traditional path analytic techniques (cf., Duncan, 1975) in estimating relationships among observed

variables. While procedures are useful, they make it difficult to separate the hypothesized causal relationships from the measurement properties of instruments used in a particular study (Kenny, 1979). This is a result of their estimating path coefficients among observed variables. The advantage of LISREL in this context is that it allows one to distinguish estimates for the proposed causal model and estimates of measurement properties of instruments. Thus, one simultaneously estimates a structural model for the former purpose and a measurement model for the latter purpose (cf., Jöreskog & Sörbom, 1978). This distinction is especially important in modeling relationships among constructs which are measured with reliabilities in the neighborhood of .60.

Throughout most of the ensuing analysis, the structural model will receive emphasis. It treats the variables designated Student Background, Motivation, and Achievement as latent variables (analogous to factors in a factor analysis), each of which has a number of indicators used to measure it. The extent to which each of the three latent variables is related to, for example, sex, race/ethnicity, the importance of mathematics, or one's understanding of mathematics is indicated by the magnitude of the path coefficients between the particular observed variable and the latent variable associated with it. Similarly, the extent to which the hypothesized causal relationships among latent variables are reflected by reliable covariation among observed variables is indicated by the magnitudes of path coefficients representing the relationship. It is important to emphasize, however, that these coefficients represent estimated relationships with variance due to measurement error removed.

Description of the Model

The educational productivity model being tested in this study is based on the covariance matrices of 11 variables for the 9-, 13- and

17-year old sample of students. The structural equation model being investigated in this study is summarized in Figure 1. The boxes in the figure represent the measurements while the circles represent the hypothetical constructs underlying the measurements. The straight-line arrows from the construct (circles) to their respective measurements (boxes) indicate that the constructs are defined by performance on the measures and are analagous to factor loadings from factor analysis. Unidentified sources of variation in the model, including random error, are represented in the figure by epsilons for the six variables measuring the endogenous constructs and by δ for the five variables identified with the single exogenous construct.

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Insert Figure 1 about here

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The straight-line arrows between constructs represent hypothesized causal relationships. Thus, for each construct an equation can be written. The equation expresses that construct in terms of other variables in the model plus a disturbance term. The disturbance terms, Φ_1, Ψ_1, and Ψ_2, represents random error and systematic variation not represented in the model. The strength of causal paths, γ_1, γ_2, and β_1, are measured by standardized regression coefficients.

Results and Discussion

The results from the multigroup LISREL analysis are given in Table 3 for each of the three age groups. The values in the table are the estimated parameters of the structural model along with their standard errors. A t-value was computed for each parameter as the estimated parameter divided by its standard error which can be used to test whether the true parameter is zero. In general, parameters whose t-values exceed two in magnitude are

judged to be different from zero. Based on the results in Table 3 it is seen that all the γ_2 and β_1 parameters are highly significant for the 13- and 17-year-old samples, while for the 9-year-old sample only the γ_2 parameter is significant.

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Insert Table 3 about here

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The γ_2 parameter reflects the direct influence of student background on student learning outcomes. This estimated parameter, significant at all ages, follows an interesting pattern across age groups. As age increases, the direct effect of student background on achievement also increases. A similar pattern for the relationship between motivation and achievement is also apparent. The β_1 estimates, which represent the direct influence of student motivation on student learning outcomes, are found to be significant for the middle and late adolescent groups. The interesting pattern that emerges from these results is the ever-increasing influence of motivation on student learning ourcomes. Harnisch (1981) noted the importance of the student motivation factor in understanding student learning outcomes by using a similar educational productivity model for a statewide sample of 11th grade students in mathematics achievement. Results from the Harnisch (1981) study found that after controlling for the student background factor, student motivation accounted for an additional 26% of the student learning outcome variance. This study suggests that student background and motivation become more important predictors of productivity measured by achievement as age increases. Although the specifications of the models of educational productivity are not the same, it is certainly clear that multiple measures of motivation do improve predictions of achievement. In

addition, more valid measures of motivation rather than internally consistent measures would provide better prediction of student learning outcomes.

The standardized solution to the LISREL model of educational productivity is given in Table 4 for the three age groups. The direct effect of student background on student learning outcomes ranges from .13 for the 9-year-old sample to a value of .39 for the 17-year-old sample. The indirect effect of student background on motivation for most practical purposes is zero given the specification of the model being tested. The magnitude of the relationship between student motivation and student learning outcomes ranges from near zero for the 9-year-old sample to a value of .25 for the 17-year-old sample. The results for a model of educational productivity used on national representative samples provide further empirical evidence of the importance of motivation in understanding student learning outcomes.

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Insert Table 4 about here

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The measurement model for student background reveals weights ranging from -.07 to .50 on the construct. Highest loadings on the background construct were found with the father's education level variable (.39, .50 and .23 for the 9-, 13- and 17-year-old samples, respectively) and the lowest loading with the race/ethnicity variables (-.04, .01 and -.07 for the 9-, 13- and 17-year-old samples, respectively). The weights for the three variables each which were associated with the student motivation and the student learning outcome construct were all positive and quite similar in magnitude.

Summary

The results of this study indicate the importance of the student background factor and the student motivation factor in understanding student learning outcomes. Significant relationships were found among student background, student motivation and student learning outcomes for the late adolescent sample. The influences of student background and student motivation on student learning outcomes were found to increase over the adolescent years.

The structural and measurement model of educational productivity presented in this paper is very useful in understanding the contribution of student background and student motivation on student learning outcomes. The measurement model described how latent variables or hyupothetical constructs were related to observed variables, and in effect described the reliability and validity of each measure. The rationale for employing LISREL models was given along with the note that the most notable advantage of these models over traditional techniques is that these models correspond to the educator's way of thinking about simultaneous equation systems and facilitate the direct estimation of substantively meaningful parameters.

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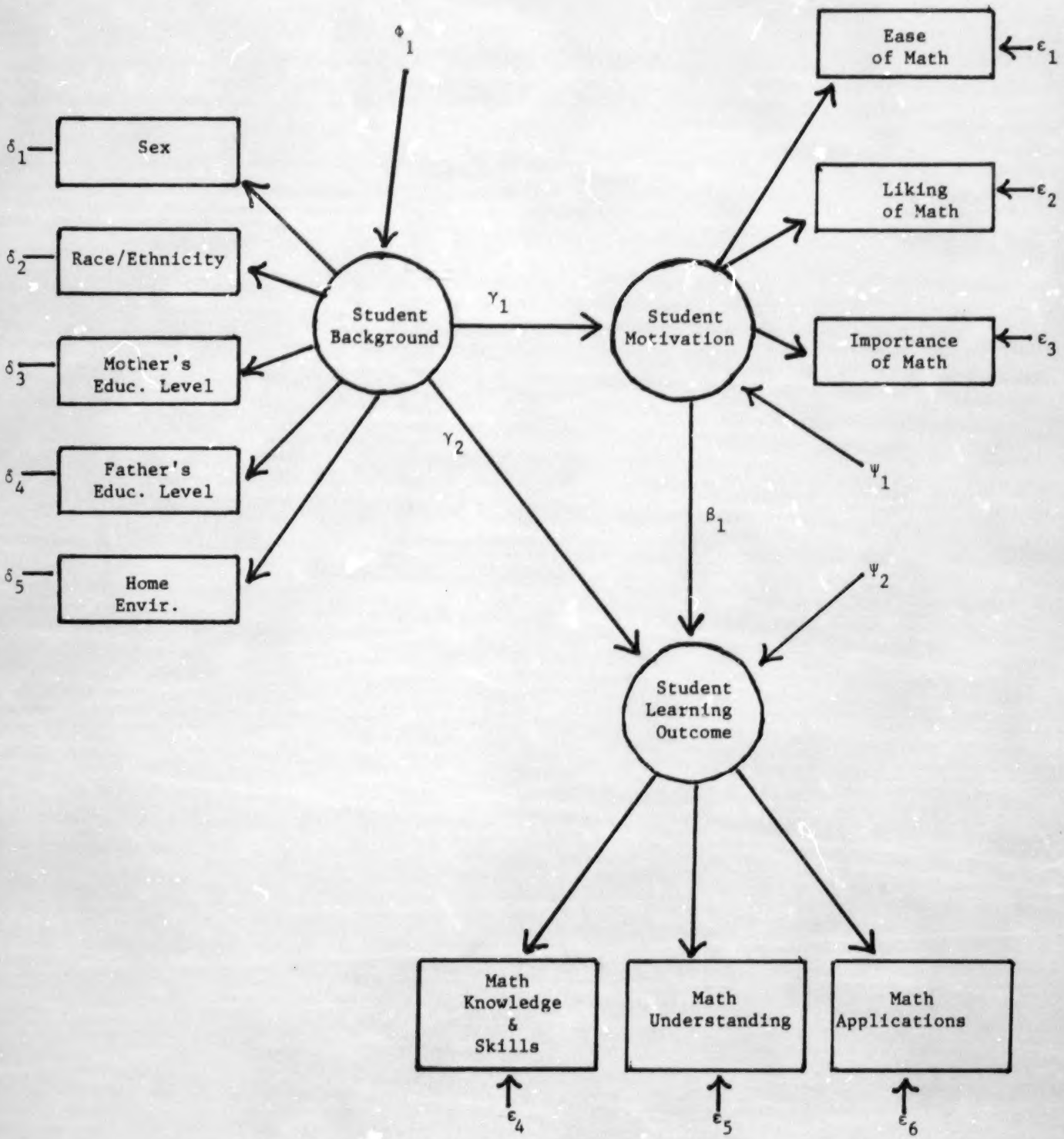

Figure 1. Structural and Measurement Model of Student Background, Motivation and Achievement in Mathematics

Table 1

Demographic Characteristics of Three NAEP Samples

Variable	Age Group 9 (N=2463)	13 (N=2462)	17 (N=2233)
Sex			
Male	.49	.48	.49
Female	.51	.52	.51
Race/Ethnicity			
White	.73	.76	.75
Non-white	.27	.24	.25
Father's Education			
College Grad	.32	.24	.23
Non-college grad	.68	.76	.77
Mother's Education			
College Grad	.31	.20	.19
Non-college grad	.69	.80	.81

Table 2

Selected Variable Description

Variable	Description and Example
Home Environment	4 - item composite, e.g., "Does your family receive a magazine regularly?" Scored (1) yes (0) no.
Liking Mathematics	5 to 6 - item composite, e.g., "Like doing mathematics homework", Scored (1) Strongly Disagree to (5) Strongly Agree.
Ease of Mathematics	5 to 6 - item composite, e.g., "Feel it is easy to work with fractions," Scored (1) Strongly Disagree to (5) Strongly Agree.
Importance of Mathematics	5 to 6 - item composite, e.g., "Feel solving word problems is important," Scored (1) Strongly Disagree to (5) Strongly Agree.
Knowledge and Skills	Multi-item composite based on NAEP item classification e.g., "Estimate .239 divided by .4 to the closest .1," Scored (1) correct or (0) incorrect.
Understanding	Multi-item composite based on NAEP item classification, e.g., "Are the following two rectangles congruent?" Scored (1) correct or (0) incorrect.
Applications	Multi-item composite based on NAEP item classification, e.g., "If a car can go 8 kilometers in 5 minutes, how far can it go in 1 hour?" Scored (1) correct or (0) incorrect.

Table 3

LISREL Estimates and Associated Standard Errors* to LISREL Model of Educational Productivity for Three NAEP Samples

	Age Group		
	9	11	17
Gamma			
Background with motivation	-.06 (.04)	-.01 (.04)	.00 (.03)
Backgound with math achievement	.23 (.04)	.42**(.08)	.66**(.06)
Beta			
Motivation with math achievement	.01 (.03)	.08**(.02)	.19**(.02)
Disturbance Terms			
PHI (Background)	.04**(.01)	.02**(.01)	.06**(.01)
PSI (Motivation)	.11**(.02)	.05**(.01)	.02**(.001)
PSI (Achievement)	.01**(.004)	.14**(.01)	.08**(.004)

*Standard errors given in parenthesis to the right of each LISREL estimate.

**Significant estimates based on t-values exceeding 2.00.

Table 4

Standardized Solution to LISREL Model of Educational Productivity for Three NAEP Samples

	Age Group		
	9	13	17
Lambda Y			
Liking of mathematics	.25	.25	.25
Ease of mathematics	.08	.20	.22
Importance of mathematics	.09	.20	.17
Math knowledge and skills	.33	.33	.33
Math understanding	.44	.18	.38
Math applications	.56	.20	.39
Lambda X			
Race/Ethnicity	-.04	.01	-.07
Sex	.01	.03	.05
Father's education level	.39	.50	.23
Mother's education level	.39	.38	.19
Home environment	.20	.20	.20
Beta			
Motivation with math achievement	-.01	.10	.25
Gamma			
Background with motivation	-.05	-.01	.01
Background with math achievement	.13	.25	.39